

---

Citation:

Helme, M and Low, C and Emmonds, S and Bishop, C (2018) The Validity and Reliability of the Rear Foot Elevated Split Squat 5RM to Determine Unilateral Leg Strength Symmetry. In: 6th International National Strength and Conditioning Conference, 26 September 2018 - 29 September 2018, Madrid. (Unpublished)

Link to Leeds Beckett Repository record:

<https://eprints.leedsbeckett.ac.uk/id/eprint/5367/>

Document Version:

Conference or Workshop Item (Presentation)

---

The aim of the Leeds Beckett Repository is to provide open access to our research, as required by funder policies and permitted by publishers and copyright law.

The Leeds Beckett repository holds a wide range of publications, each of which has been checked for copyright and the relevant embargo period has been applied by the Research Services team.

We operate on a standard take-down policy. If you are the author or publisher of an output and you would like it removed from the repository, please [contact us](#) and we will investigate on a case-by-case basis.

Each thesis in the repository has been cleared where necessary by the author for third party copyright. If you would like a thesis to be removed from the repository or believe there is an issue with copyright, please contact us on [openaccess@leedsbeckett.ac.uk](mailto:openaccess@leedsbeckett.ac.uk) and we will investigate on a case-by-case basis.



## LINKING SPORT SCIENCE AND APPLICATION

### The Validity and Reliability of the Rear Foot Elevated Split Squat 5RM to Determine Unilateral Leg Strength Symmetry

**Mark Helme, ASCC, BSc, PGCE, PGD**



LEEDS BECKETT UNIVERSITY  
CARNEGIE SCHOOL OF SPORT

# Acknowledgements

## PhD Supervisory Team

- [Dr Chris Low](#)
- [Dr Stacey Emmonds](#)

## Co-Author

- [Chris Bishop](#)



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

# Introduction

- Asymmetry is of interest to both researchers and practitioners as there is evidence to suggest that it may be linked to an increased risk of injury and reduced performance, although this is equivocal (4,11).
- Previous methods of measuring strength asymmetry have used lab based methods requiring either isokinetic dynamometry or twin force plates.
  - Lab based Isokinetic dynamometry (6, 13, 14, 16)
  - Field based force plate measurements
    - Isometric Mid thigh pull (8), Isometric back squat (9)
- The aim of this study was to validate a method of determining a field based test of unilateral leg strength and subsequent symmetries, which did not require direct measurement of force.
- Increased ecological validity and practicality for S&C coaches

WWW.NSCA2018.COM

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# Introduction



- Measurement of symmetry using free weight exercises required a unilateral task
- The rear foot elevated split squat (RFESS) was identified as the preferred exercise.
- DeForest et al. (6) reported peak force in the RFESS ( $1412.3 \pm 258.6$  N) as being similar to the back squat ( $1414.8 \pm 251.0$  N), but the split squat as significantly lower ( $1198.6 \pm 187.9$  N,  $p < 0.05$ ).
- McCurdy et al., (11) reported the RFESS as a reliable measure of unilateral leg strength (IRM ICC, 0.97- 0.99, 3RM, 0.94-0.97).
- The RFESS was identified as a reliable measure of unilateral leg strength which is kinetically comparable to the back squat.
- Found to be comparable to the back squat at developing strength and speed (14)



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED





# Methods

With ethical approval 26\* resistance trained male subjects,  
3 visits to the lab

1. Familiarization
  2. Test
  3. Re-test.
- 5 continuous repetitions, with no pause or bilateral stance within 30s data capture window.
  - Only toe of the rear foot placed on the force plate
  - Force plates under front and rear foot, 10 Qualysis 3D motion capture cameras.
  - 5 attempts to achieve maximal load.



\*17 participants complete test and re-test conditions



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

# Methods



- Each set recorded using a PUSH wearable device and repetitions in reserve rating of perceived exertion (RIR-RPE).
- Zourdos et al., (15) reported a mean RIR-RPE of 9.6-10 for 1RM Back squat.
- Concentric velocity for maximal strength testing 1RM backs squats have been reported as  $0.24 \pm 0.04$  m.s.<sup>-1</sup> (17),  $0.28 \pm 0.07$  m.s.<sup>-1</sup> (5)
- Mean concentric velocity (MCV) calculated on the 5<sup>th</sup> repetition and set RIR-RPE recorded after each trial.
- Criteria to achieve a valid maximal attempt.
  - RIR-RPE of 9.5 or greater  
and
  - MCV of less than  $0.28$  m.s.<sup>-1</sup>
- RIR-RPE scores from submaximal trials was used to predict maximal load and reduce number of trials required.

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# Symmetry Calculations

The method of calculating symmetry has been varied across previous research, disagreement between methods in symmetry found from same data set (3). Symmetry was calculated, using a modified percentage difference method. (3)

$$((100/(\max \text{ value}))-(\min \text{ value}) \times (-1)+100)\text{IF}(\text{left}<\text{right}, 1, -1))+100^*$$

- A score of less than 100 indicates the left limb achieved a greater score than the right, conversely greater than 100, the right performed better.
- Data not normally distributed and was log transformed
- All data reported at 95% confidence limits.

\*symmetrical score of 100 can be log transformed, where asymmetry value of 0 could not.



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



# Results



- The mean bar load of all successful trials from both limbs and test conditions was 84kg  $\pm$  16.8kg (0.96  $\pm$  0.18 kg/kg).
- Between test and re-test conditions a most likely very large positive correlation ( $r = 0.93$ , 0.88-0.96), excellent level of reliability was found (ICC = 0.93 CL 0.88-0.96). A most likely positive increase (9.3%) in bar load was observed between test and re-test conditions

	Test 1		Test 2	
	Left	Right	Left	Right
Mean bar load (kg) $\pm$ SD	80.9 $\pm$ 15.2	82.0 $\pm$ 16.37	89.5 $\pm$ 16.3	88.8 $\pm$ 18.2
Mean bar load, normalised to body mass (kg/kg) $\pm$ SD	0.92 $\pm$ 0.17	0.94 $\pm$ 0.19	1.0 $\pm$ 0.2	0.99 $\pm$ 0.2

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



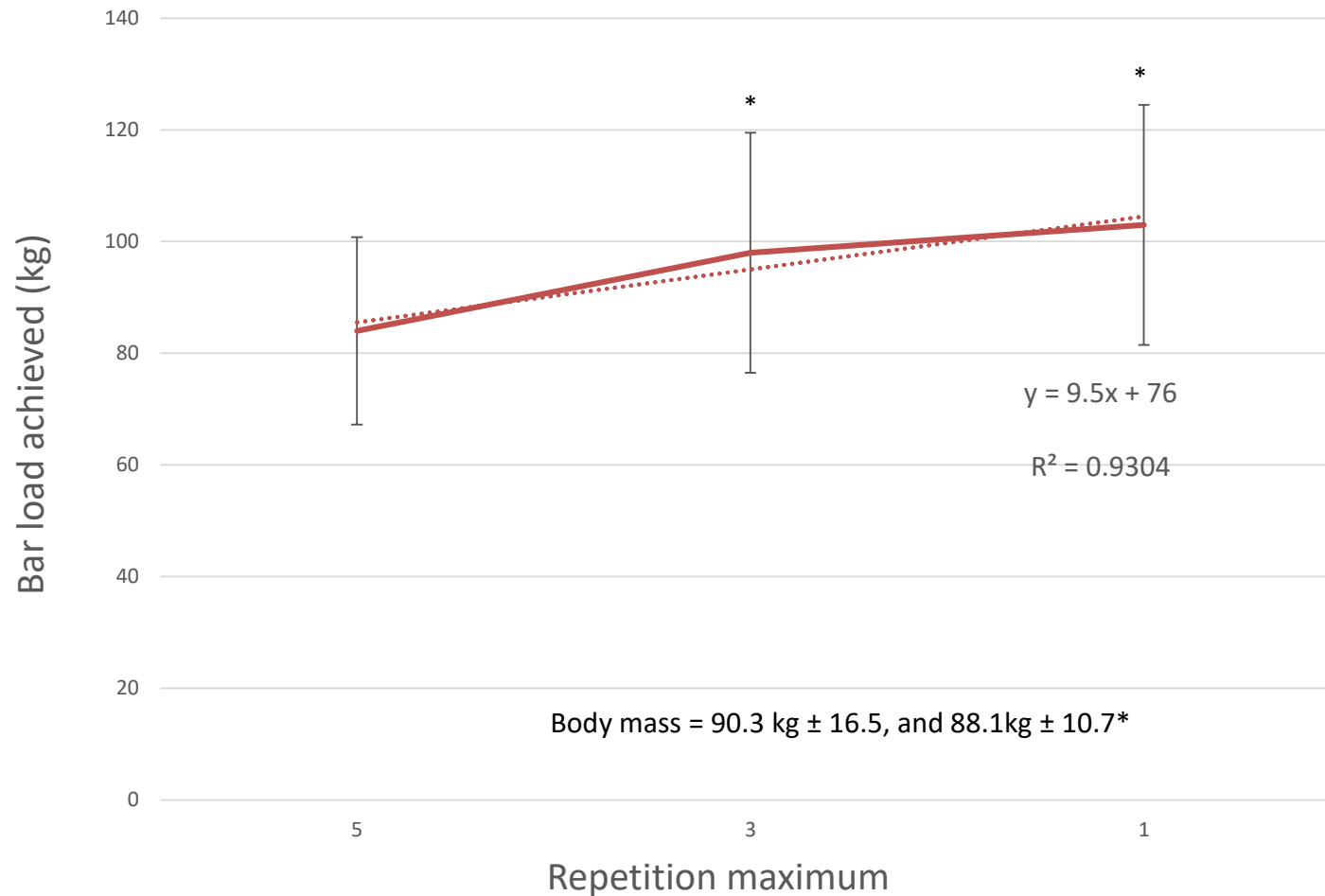
Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# Mean bar loads achieved during a RFESS maximal strength test



\* MCCURDY, K., LANGFORD, G. A., CLINE, A. L., DOSCHER, M. & HOFF, R. 2004. The reliability of 1- and 3rm tests of unilateral strength in trained and untrained men and women. *Journal of Sports Science & Medicine*, 3, 190-196. (12)



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

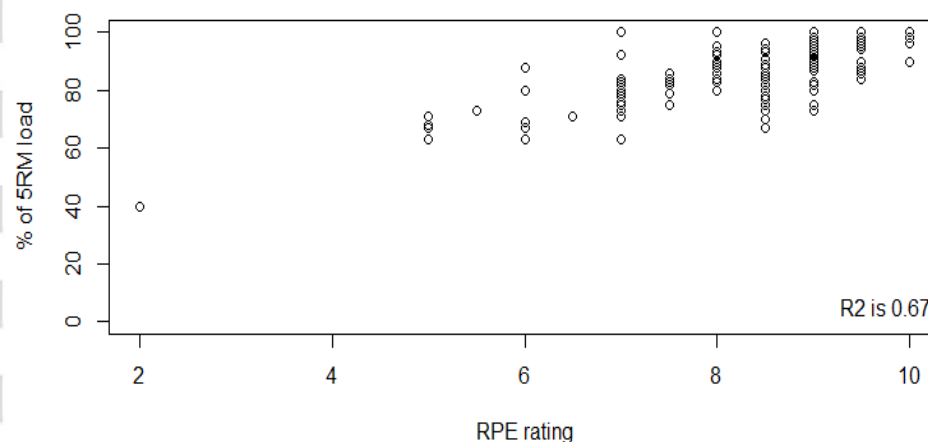
26-29 SEPTEMBER, 2018  
MADRID, SPAIN

# Results

- Pearson product moment correlation found a most likely very large positive correlation between the percentage of 5RM and RIR-RPE indicated
- $r = 0.82, 0.77-0.86$ .
- The mean RPE rating indicated for all maximal trials was  $9.6 \pm 0.8$  (CV =8%),

RESISTANCE EXERCISE-SPECIFIC RATING OF PERCEIVED EXERTION (RPE)

Rating	Description of Perceived Exertion
10	Maximum effort
9.5	No further repetitions but could increase load
9	1 repetition remaining
8.5	1-2 repetitions remaining
8	2 repetitions remaining
7.5	2-3 repetitions remaining
7	3 repetitions remaining
5-6	4-6 repetitions remaining
3-4	Light effort
1-2	Little to no effort

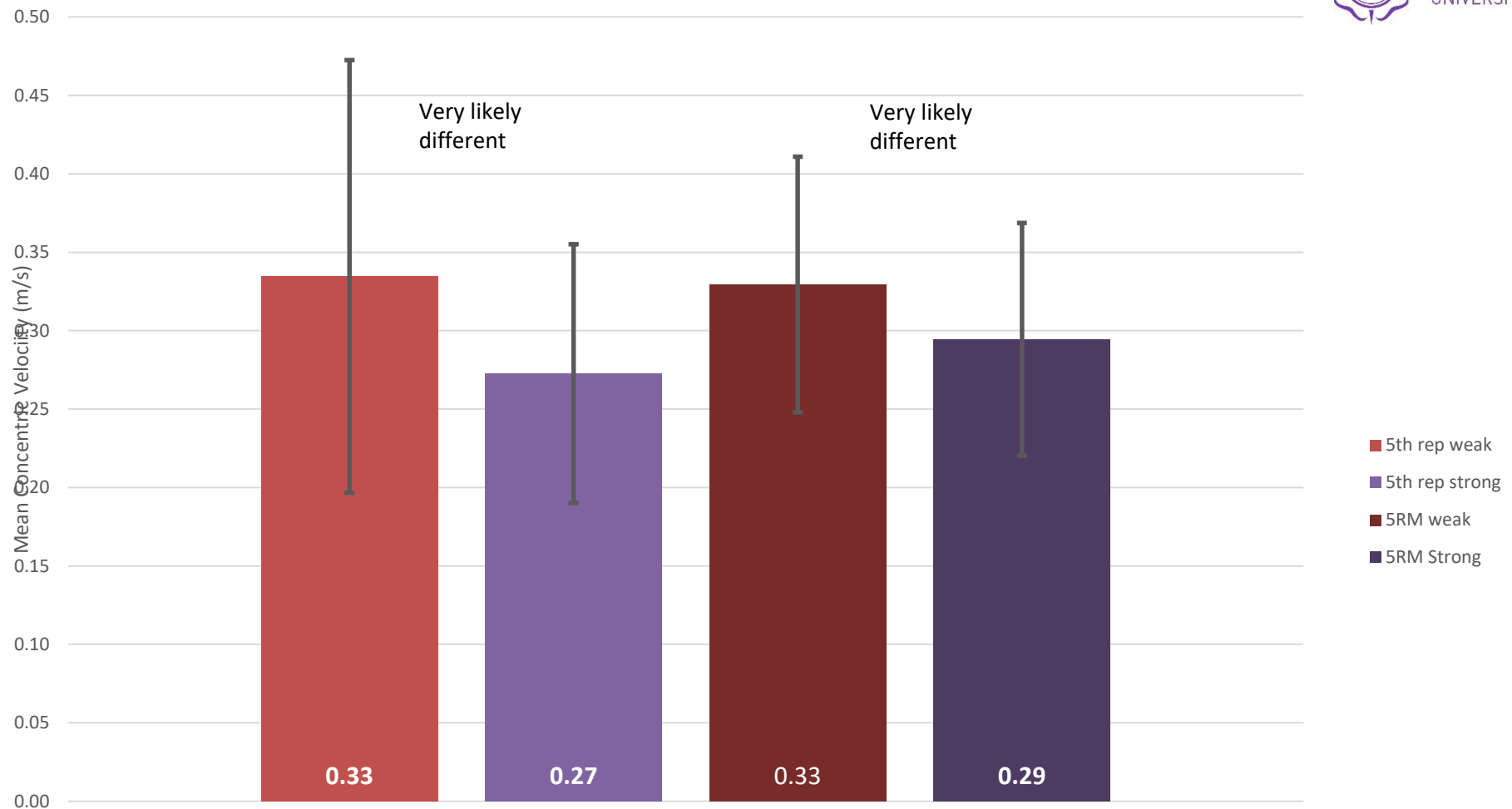


INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

WWW.NSCA2018.COM

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

## Comparison of mean concentric velocity between stronger and weaker participants in a RFESS 5RM



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

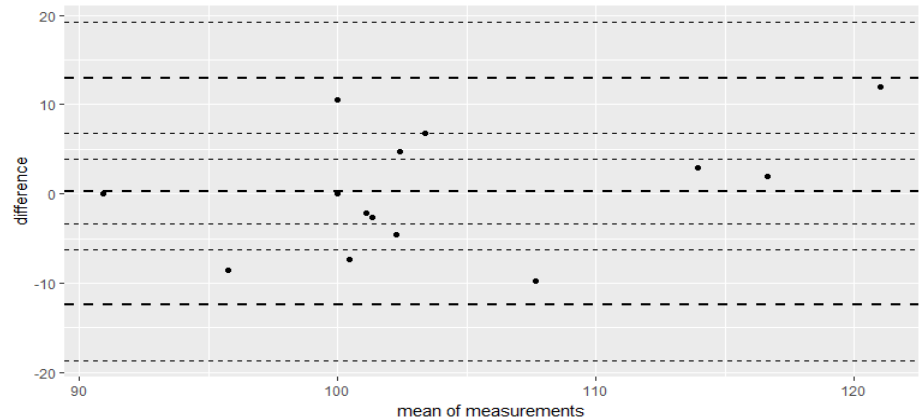
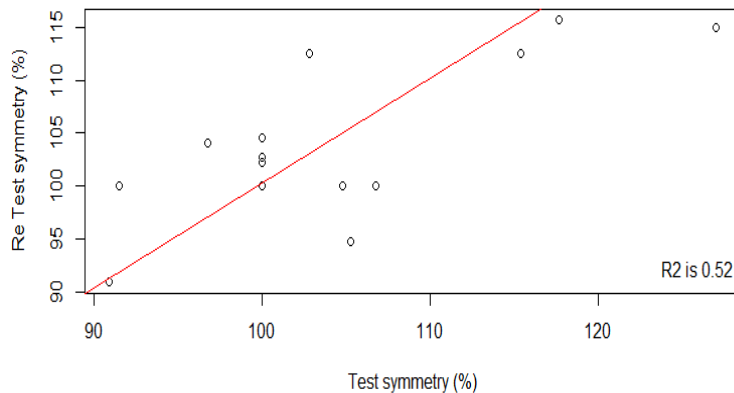
[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

# Results (Symmetry Reliability)



Mean symmetry (all trials)	Standard error of the mean	Mean symmetry (test 1)	Mean symmetry (test 2)	ICC (95% confidence interval)
102.15± 7.95%	1.29%	99.67 ±18.77%,	102.84 ± 6.35%)	0.73, 0.39-0.89



[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Escuela Universitaria  
Real Madrid  
Universidad Europea



Universidad  
Europea

NSCA CEU  
APPROVED





# Results

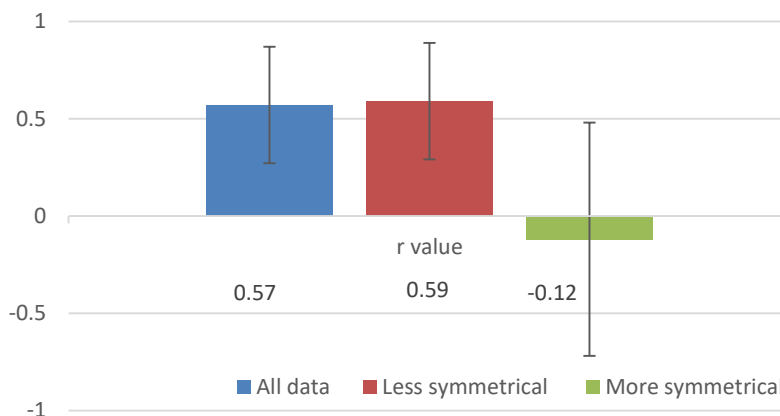
## (Symmetry Validity)



	r value	Beneficial or substantially positive effect	Negligible or Trivial effect	Harmful or substantially negative effect
Mean lead foot only vGRF (N)	0.57, (0.30 to 0.76)	99.9% very likely	0.1% very unlikely	0.0% most unlikely
Mean lead and rear foot vGRF (N)	0.63, (0.39 to 0.79)	100% very likely	0.0% very unlikely	0.0% most unlikely

Most likely large positive correlation between symmetry of bar load and lead foot vGRF

Most Comparison of Correlation analysis between bar load symmetry and lead foot vGRF symmetry



Symmetry threshold = (Mean load asymmetry – 100) + (1.64 + Standard Error of the Mean) (1).

Threshold boundaries of load asymmetry (94.91% - 105.9%)

WWW.NSCA2018.COM

26-29 SEPTEMBER, 2018  
MADRID, SPAIN

INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# Practical Applications



- The findings from the current study indicate that the RFESS is a reliable method of determining unilateral leg strength in a field setting.
- Valid method of measuring leg strength symmetry, without the need for force plates or isokinetic dynamometry
- Specific threshold of asymmetry detection for this sample  $\pm 5.09\%$ 
  - Thresholds may change for different populations.
- Athlete experience and competence can affect their ability to achieve a true 5RM value, familiarisation is required. (16)
- Increased validity if the guidelines below are achieved
  - MCV of 5th repetition  $\leq 0.27\text{m/s}$
  - RIR-RPE  $\geq 9.5$

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION



Universidad Europea



# References



1. Araújo SRS, Medeiros FB, Zaidan AD, Pimenta EM, de Campos Abreu EA, and Ferreira JC. Comparison of two classification criteria of lateral strength asymmetry of the lower limbs in professional soccer players. / Comparação de dois critérios de classificação de jogadores de futebol profissional da assimetria lateral de força dos membros inferiores. Brazilian Journal of Kineanthropometry & Human Performance 19: 644-651, 2017.
2. Banyard HG, Nosaka K, and Haff GG. Reliability and Validity of the Load-Velocity Relationship to Predict the 1rm Back Squat. J Strength Cond Res 31: 1897-1904, 2017.
3. Bishop C, Read P, Lake J, Chavda S, and Turner A. Interlimb Asymmetries: Understanding How to Calculate Differences From Bilateral and Unilateral Tests. Strength & Conditioning Journal 40: 1-6, 2018.
4. Bishop C, Turner A, and Read P. Effects of inter-limb asymmetries on physical and sports performance: a systematic review. J Sports Sci 36: 1135-1144, 2018.
5. Carroll KM, Sato K, Bazylar CD, Triplett NT, and Stone MH. Increases in Variation of Barbell Kinematics Are Observed with Increasing Intensity in a Graded Back Squat Test. Sports 5: 51, 2017.
6. Daneshjoo A, Rahnama N, Mokhtar AH, and Yusof A. Bilateral and Unilateral Asymmetries of Isokinetic Strength and Flexibility in Male Young Professional Soccer Players. Journal of Human Kinetics 37: 45-53, 2013.
7. DeForest B, Cantrell GS, and Schilling BK. Muscle Activity in Single- vs. Double-Leg Squats. Int J Exerc Sci 7: 302-310, 2014.



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# References



8. Dos'Santos T, Thomas C, Jones PA, and Comfort P. Assessing Muscle Strength Asymmetry Via a Unilateral Stance Isometric Mid-Thigh Pull. *Int J Sports Physiol Perform*: 1-24, 2016.
9. Hart N.H., Nimphius S., Cochrane JL, and Newton RU. Reliability and validity of unilateral and bilateral isometric strength measures using a customised, portable apparatus. *Journal of Australian Strength and Conditioning Journal* 20: 60-67, 2012.
10. Helms ER, Cronin J, Storey A, and Zourdos MC. Application of the Repetitions in Reserve-Based Rating of Perceived Exertion Scale for Resistance Training. *Strength Cond J* 38: 42-49, 2016.
11. Maloney S. The Relationship Between Asymmetry and Athletic Performance: A Critical Review. *The Journal of Strength & Conditioning Research*: 1, 2018.
12. McCurdy K, Langford GA, Cline AL, Doscher M, and Hoff R. The reliability of 1- and 3rm tests of unilateral strength in trained and untrained men and women. *Journal of Sports Science & Medicine* 3: 190-196, 2004.
13. Newton RU, Gerber A, Nimphius S, Shim JK, Doan BK, Robertson M, Pearson DR, Craig BW, Häkkinen K, and Kraemer WJ. DETERMINATION OF FUNCTIONAL STRENGTH IMBALANCE OF THE LOWER EXTREMITIES. *Journal of Strength & Conditioning Research* (Allen Press Publishing Services Inc) 20: 971-977, 2006.



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED



# References



14. O'Connor D. Groin injuries in professional rugby league players: a prospective study. J Sports Sci 22: 629-636, 2004.
15. Speirs DE, Bennett MA, Finn CV, and Turner AP. UNILATERAL VS. BILATERAL SQUAT TRAINING FOR STRENGTH, SPRINTS, AND AGILITY IN ACADEMY RUGBY PLAYERS. Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins) 30: 386-392, 2016
16. Tourny-Chollet C, Leroy D, eger HL, and Beuret-Blanquart F. Isokinetic knee muscle strength of soccer players according to their position. Isokinetics & Exercise Science 8: 187, 2000.
17. Zourdos MC, Klemp A, Dolan C, Quiles JM, Schau KA, Jo E, Helms E, Esgro B, Duncan S, Merino SG, and Blanco R. Novel Resistance Training-Specific Rating of Perceived Exertion Scale Measuring Repetitions in Reserve. J Strength Cond Res 30: 267-275, 2016.



INTERNATIONAL CONFERENCE  
LINKING SPORT SCIENCE AND APPLICATION

[WWW.NSCA2018.COM](http://WWW.NSCA2018.COM)

26-29 SEPTEMBER, 2018  
MADRID, SPAIN



Escuela Universitaria  
Real Madrid  
Universidad Europea



NSCA CEU  
APPROVED

